

# Climate Change and Water in California

by Maurice Roos  
CA DWR

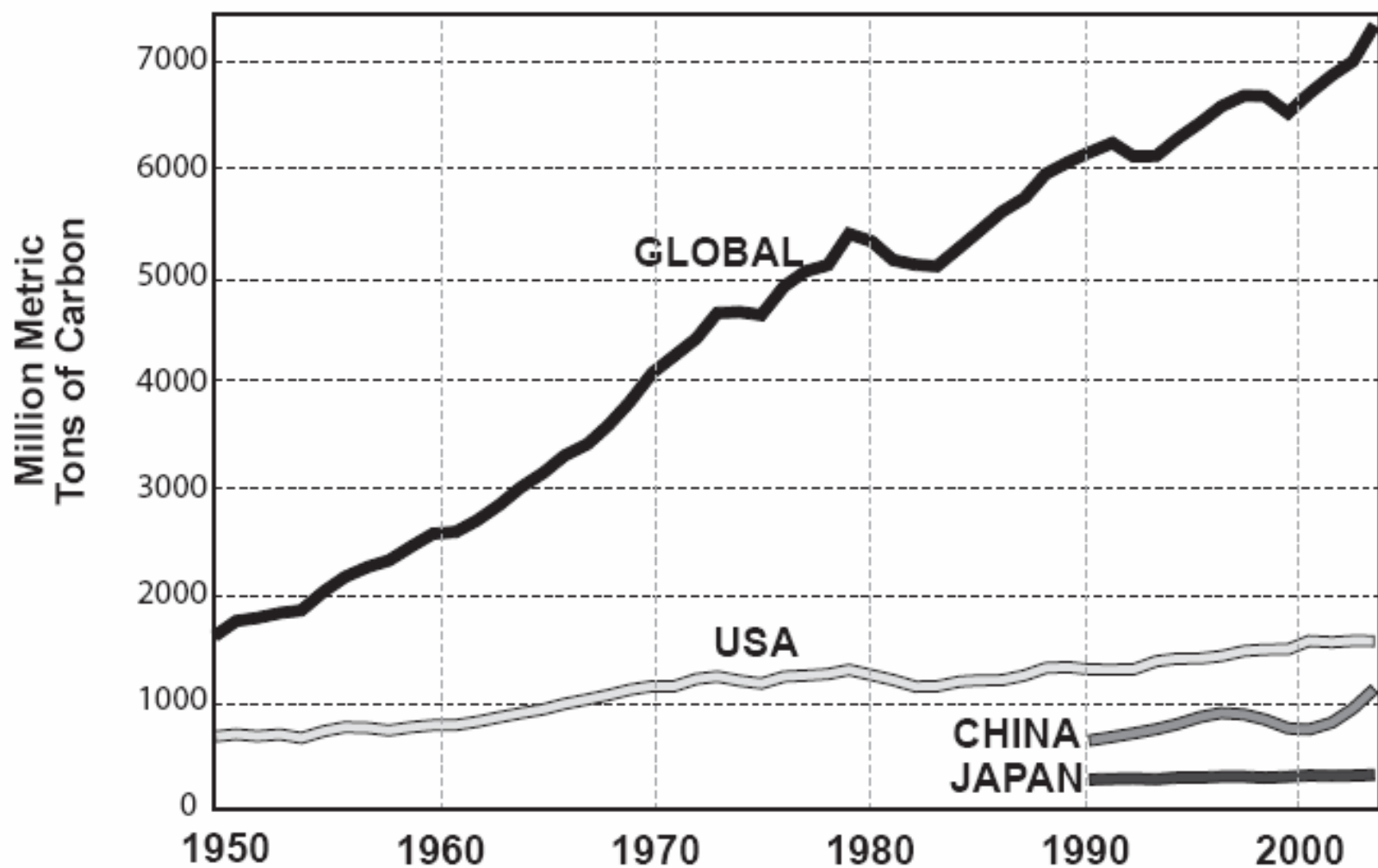
May '07

# Major Greenhouse Gases

	Approx Percent	Rel GWP
Carbon dioxide	55	1
Methane	17	23
Nitrous oxide	5	300
Halocarbons	11	140 – 12,000
Trop. ozone	12	N.A.

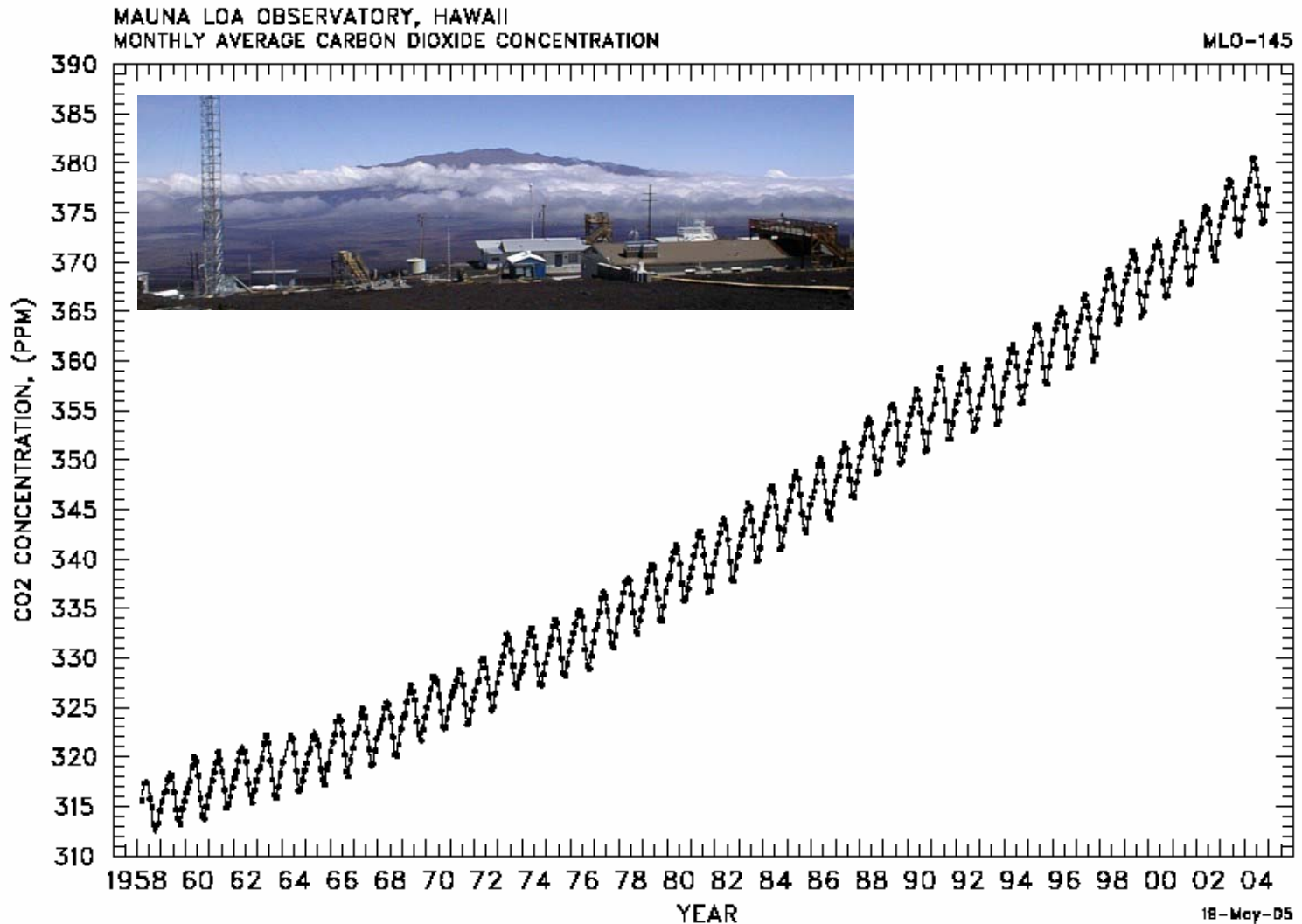
Water vapor      About 2/3 of present GH  
effect; CO<sub>2</sub> is about 25 %

## CO2 Emissions From Fossil Fuel, 1950-2003



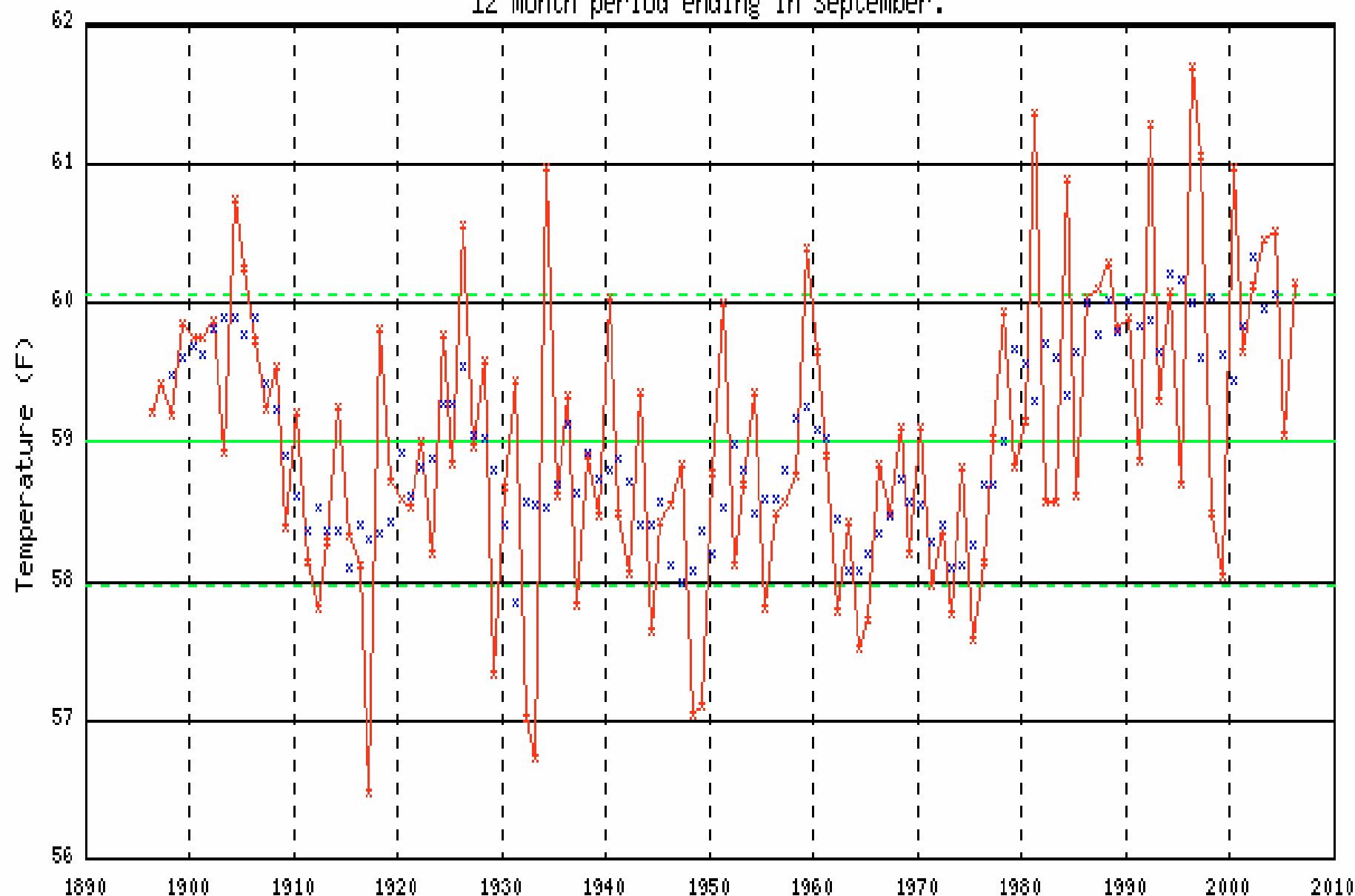
Source: CDIAC, Oak Ridge, TN

# Atmos. CO<sub>2</sub> on Mauna Loa



# California Temperature (F)

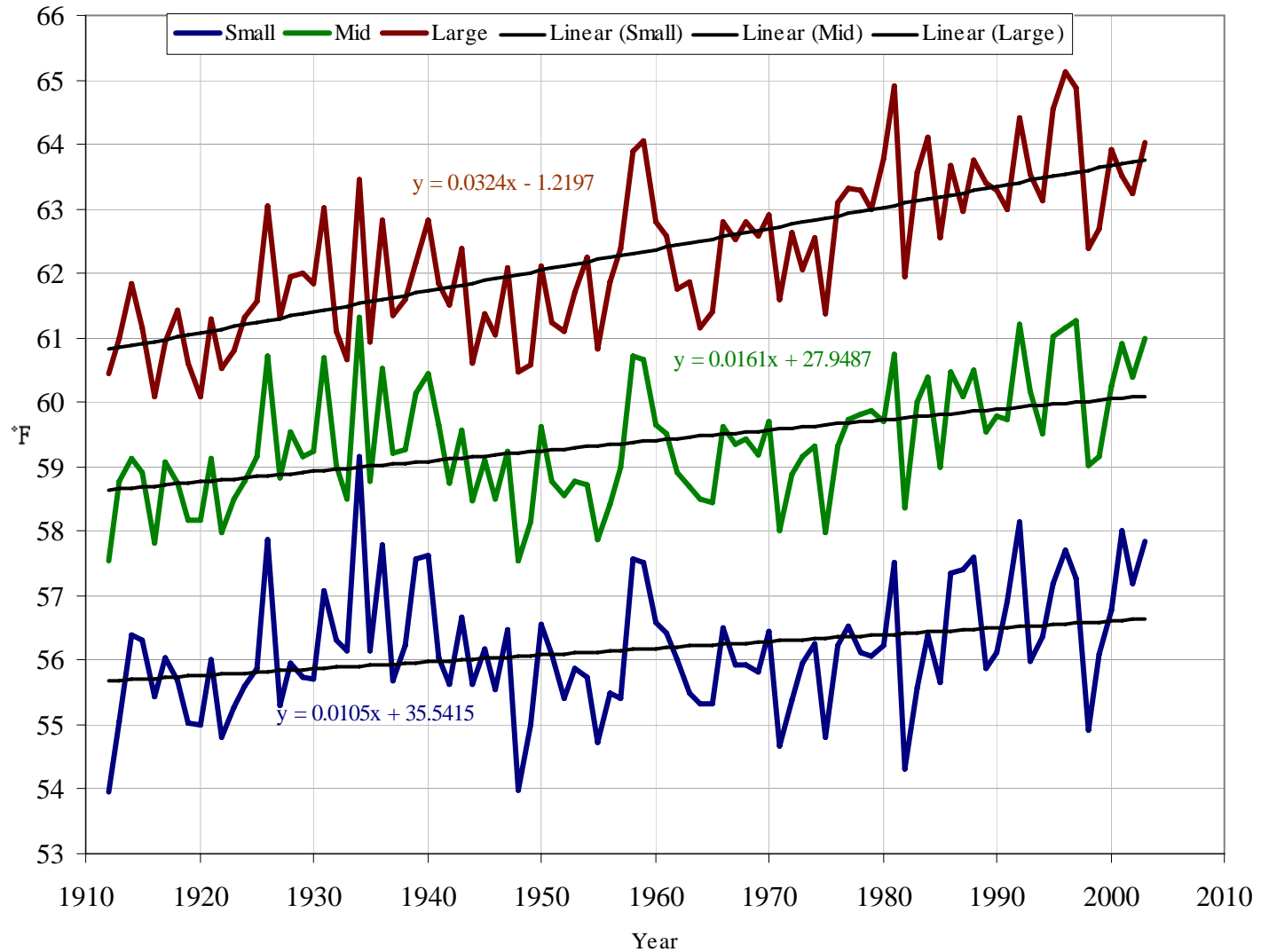
12 month period ending in September.



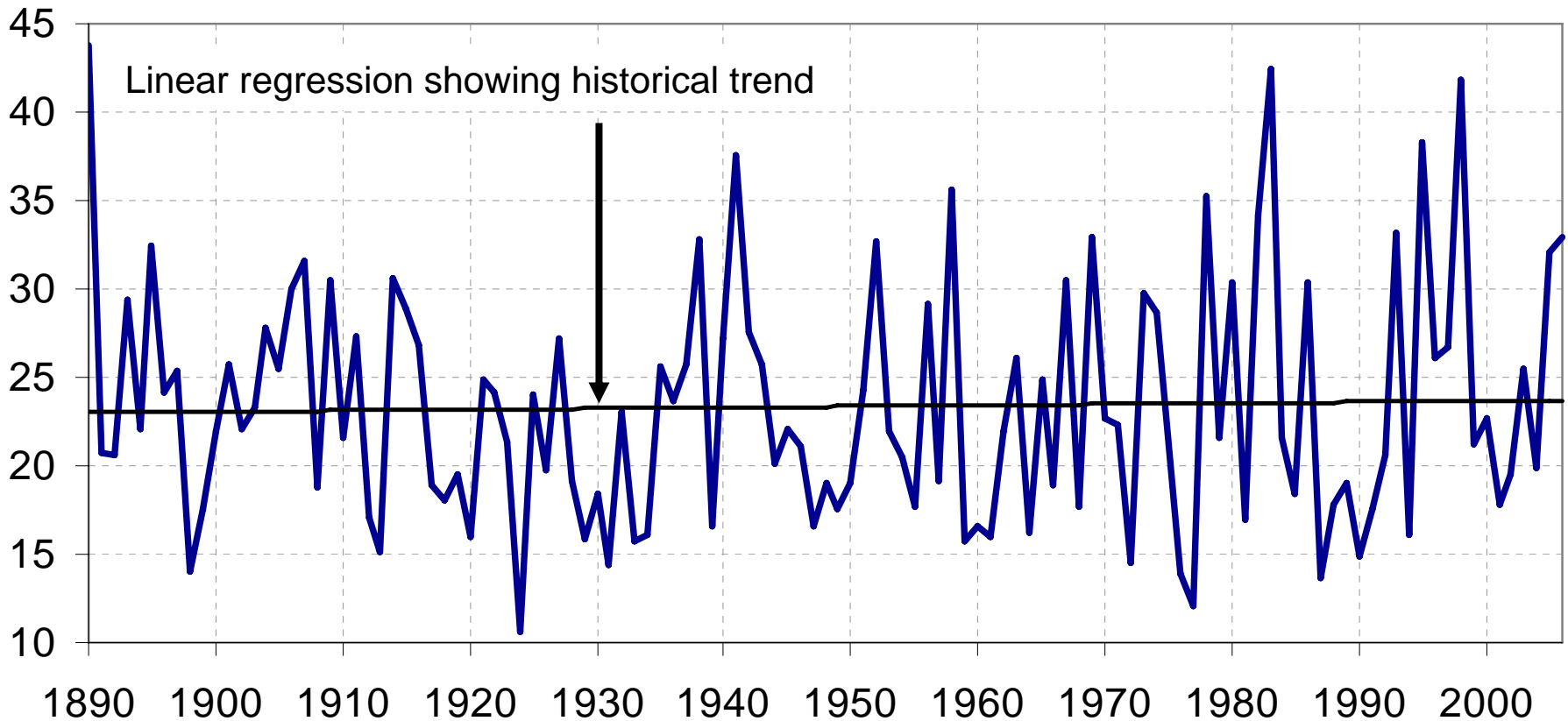
# Average Temperature at 65 California Stations

Stratified by 1990 County Population

Large over 1 Million, Small less than 100,000



# Ca Precipitation Trend



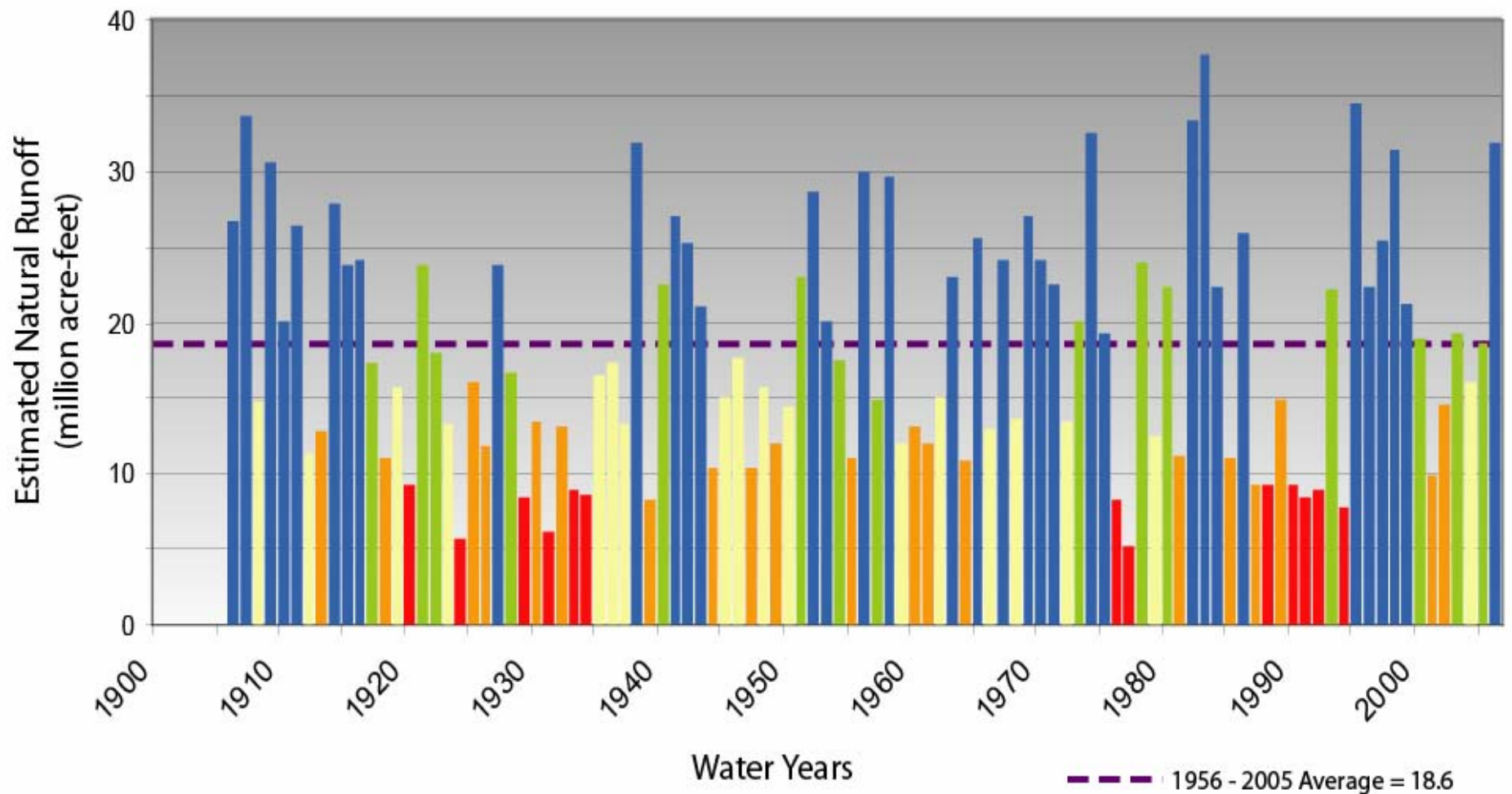
116 year average: 23.88 inches

Driest 30 years: 1908-1937 21.28 inches

Wettest 30 years: 1977-2006 24.88 inches

## Sacramento River Unimpaired Runoff Since 1906

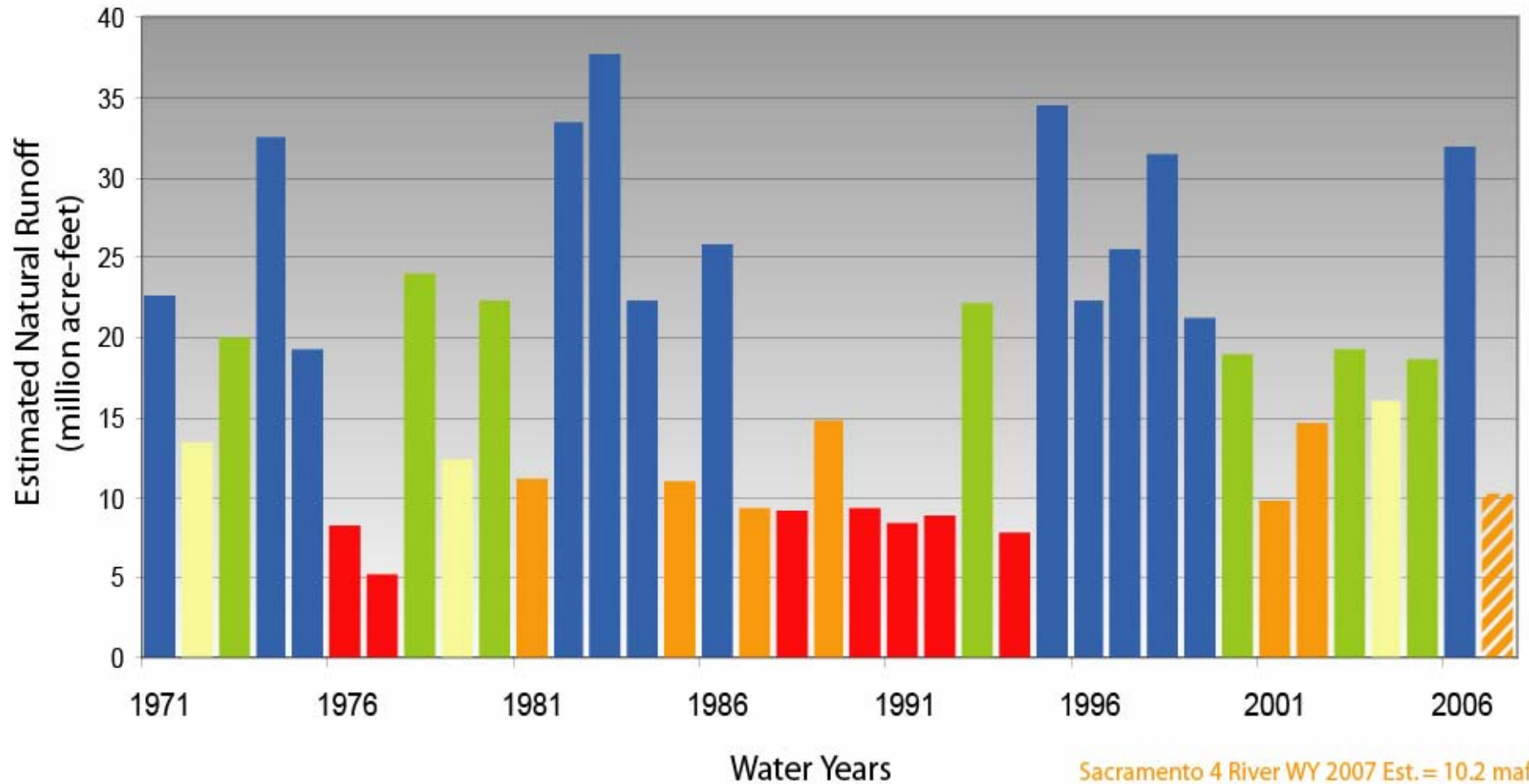
■ Wet ■ Above Normal ■ Below Normal ■ Dry ■ Critical





## Sacramento River Unimpaired Runoff Since 1971

■ Wet ■ Above Normal ■ Below Normal ■ Dry ■ Critical



# IPCC 2100 Projections

(From 2001 Third Assessment Report)

- Global temp up 1.4 to 5.8 ° C (from 1990)
- Sea level rise by .09 to .88 m (.3 to 2.9 ft)
- Precip increase at high latitudes;  
otherwise uncertain
- Extreme events (floods) more likely

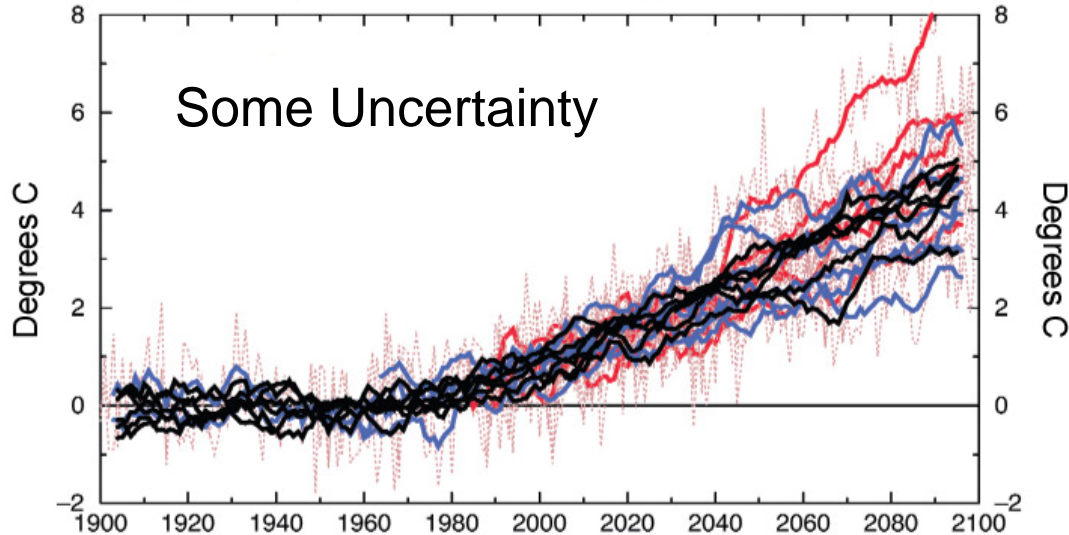
# New IPCC 2100 Projections

(From 4<sup>th</sup> Assessment Report 2007)

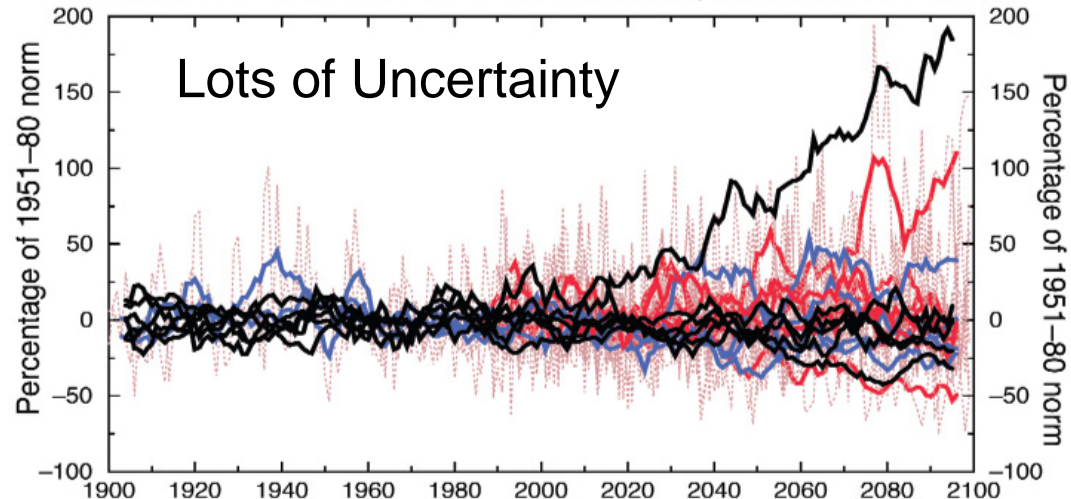
- Global temp up 1.8 to 4.0 ° C (from 1990)
- Sea level rise by .18 to .59 m (.6 to 1.9 ft)  
( with an added .1 to .2 m if Greenland ice melt increases beyond 1993-03 rate)
- Precipitation more uncertain but likely increase at higher latitudes and near equator, less in subtropics
- Extreme events (floods) more likely

# CA Temp and Precip Projections

PROJECTED CHANGES IN ANNUAL TEMPERATURE, NORTHERN CALIFORNIA



PROJECTED CHANGES IN ANNUAL PRECIPITATION, NORTHERN CALIFORNIA



From Dettinger, 2005

# Effects on CA Water Resources

- Reduced snowpack with runoff pattern shift—more winter, less spring
- Sea level rise affects Delta levee stability and salinity intrusion
- Possible bigger floods and more intense rainfall events
- Some increase in water use for ag and urban landscapes
- Warmer river temps affecting salmonids

# Reduced Mountain Snowpack and Change in River Runoff Patterns

- Warmer temperatures mean higher snow levels during winter storms, about 500 feet per degree Celsius.
- If precip about the same, more winter runoff and smaller spring and early summer snowmelt volumes.
- Northern Sierra affected more than higher elevation southern Sierra snowpack.



## Snowpack Changes:

Evolution of Average Annual Snow Water Equivalent  
as a Percentage of Average 1995-2005 Values

(effect of temperature changes only: historical P, baseline T from WY 1965-1987)



Climate Research Division

2030 SWE

2060 SWE

2090 SWE

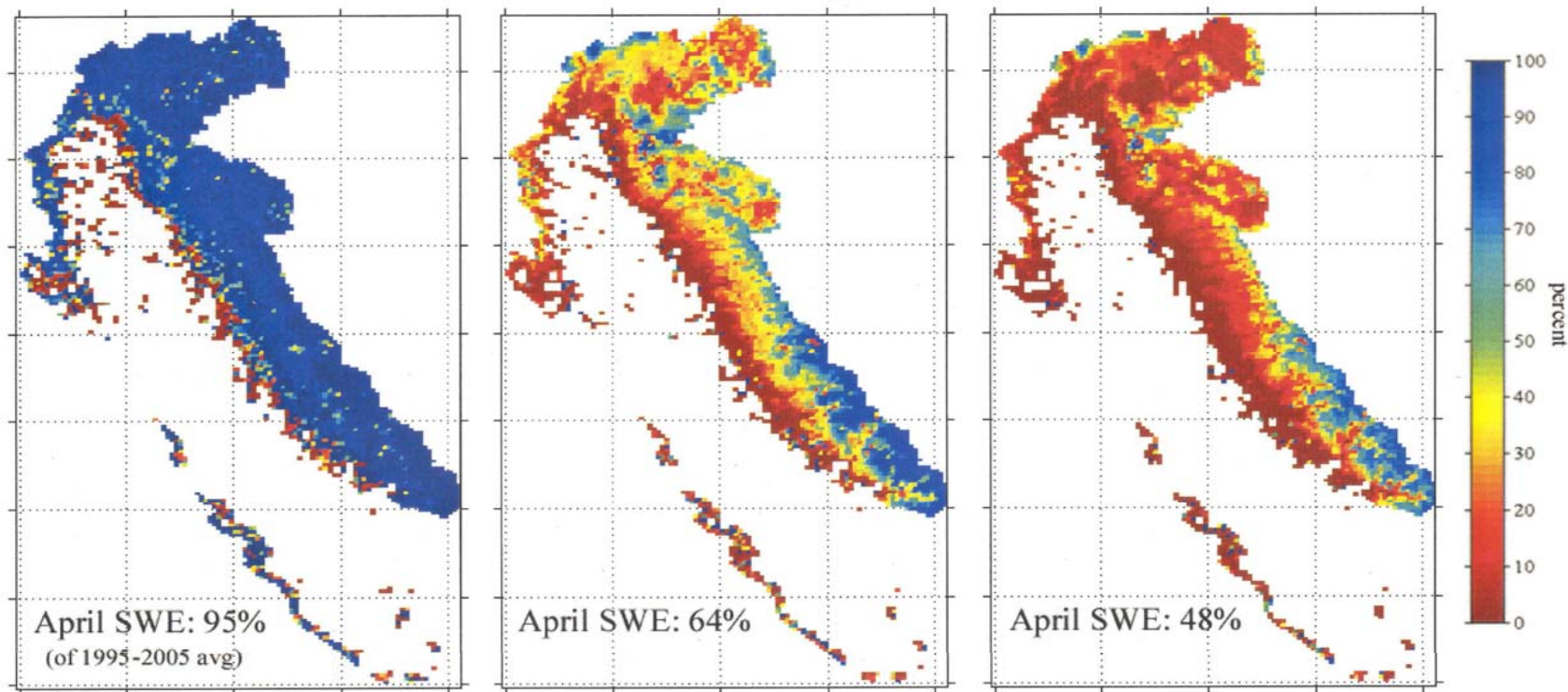
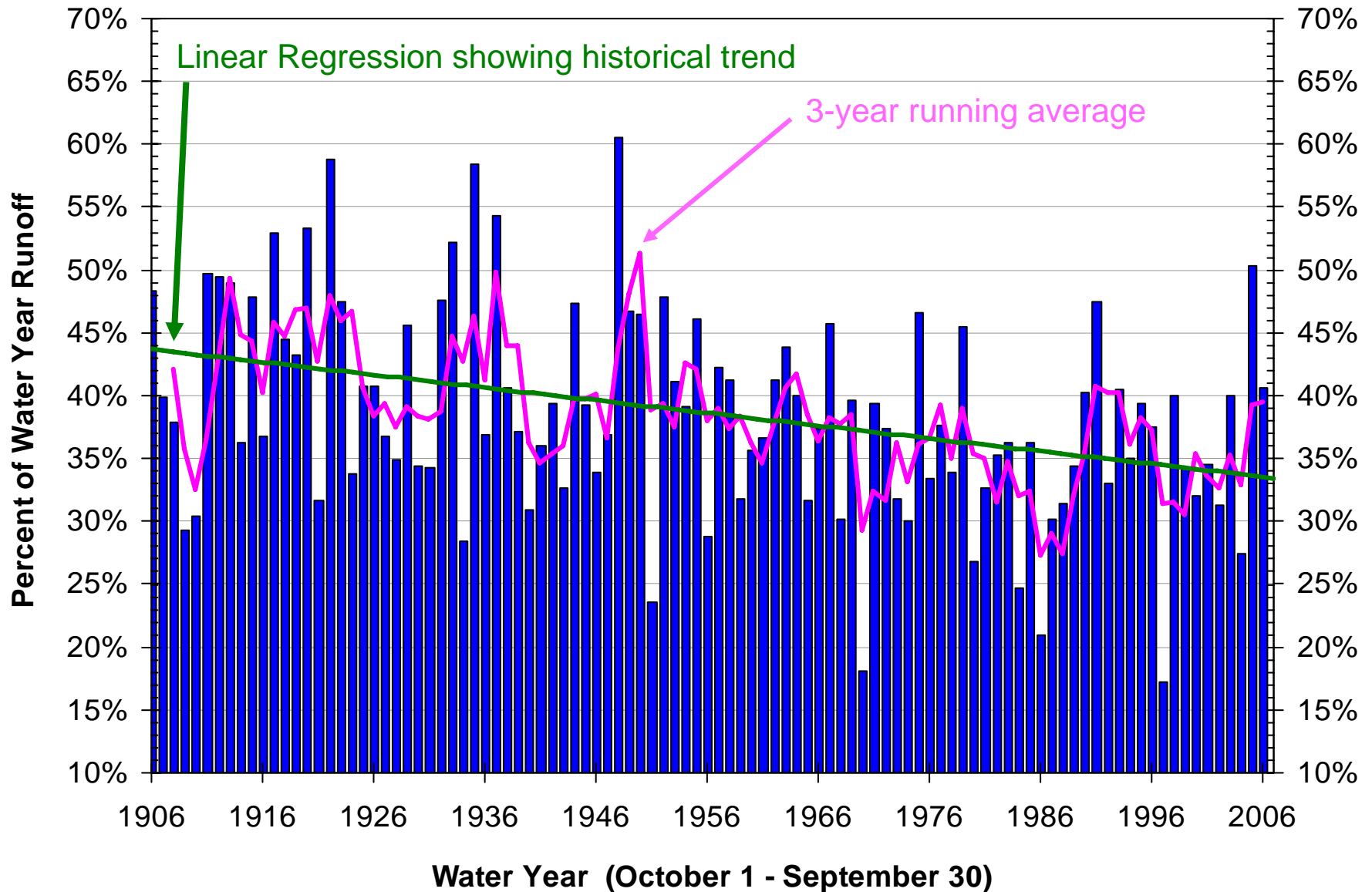


figure by N. Knowles

(20-year centered avg monthly T anoms rel to 1995-2005 monthly avgs from PCM B06.44 run, used to force BDWM with WY65-87 conditions. 6/18/01)

# Sacramento River Runoff

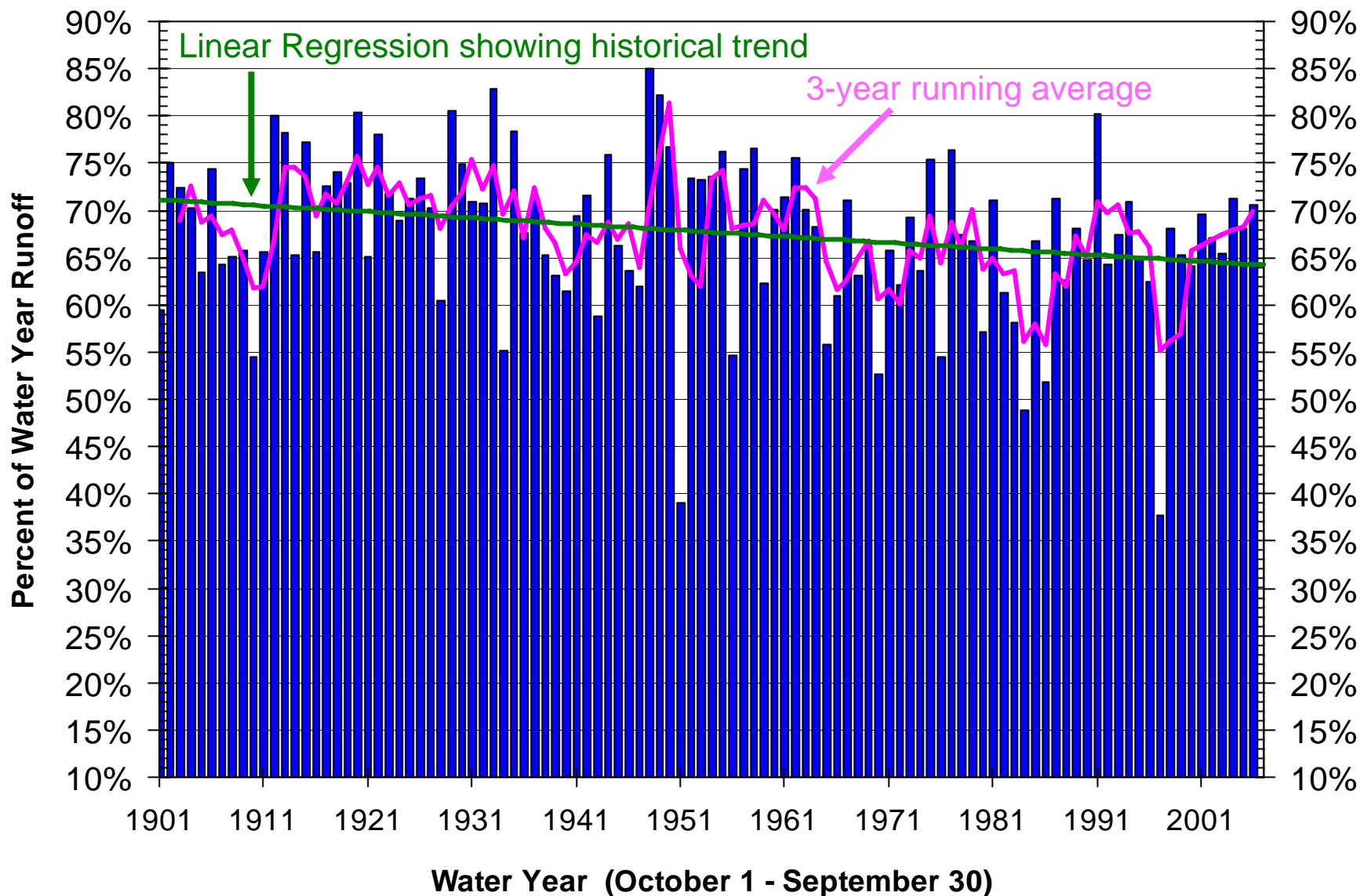
## April - July Runoff in percent of Water Year Runoff





# San Joaquin (4-River) Runoff

## April - July Runoff in percent of Water Year



# Loss of Snowpack

- Knowles & Cayan – 2002 paper
  - Temp rise                      Pack loss
  - 0.6 (2030)                      5 percent
  - 1.6 (2060)                      33        “
  - 2.1 (2090)                      50        “
- Hayhoe et al -- 2004 NAS
  - 1.3 – 2.0 (2020-49)        26 -- 40 percent
  - 2.3 – 5.8 (2070-99)        29 -- 89        “
- Cayan et al -- 2006 White Paper
  - 0.5 -- 1.5 (2005-34)        6 -- 29 percent
  - 0.8 -- 2.3 (2035-64)        12 -- 42        “
  - 1.5 -- 4.5 (2065-99)        32 -- 79        “

# Sea Level Rise

- IPCC 2001 range from 0.1 to 0.9 m
- Historic at GG = 0.2 m per century
- Major water project impacts in Delta:
  - **Increase in salinity intrusion due to higher ocean levels (deeper channels) and longer dry season (less snowmelt runoff). Can be combated by more outflow.**
  - **More pressure on weak Delta levees with greater risk of inundation in winter floods; higher risk of summer breaks with possible interference with export water transfer.**

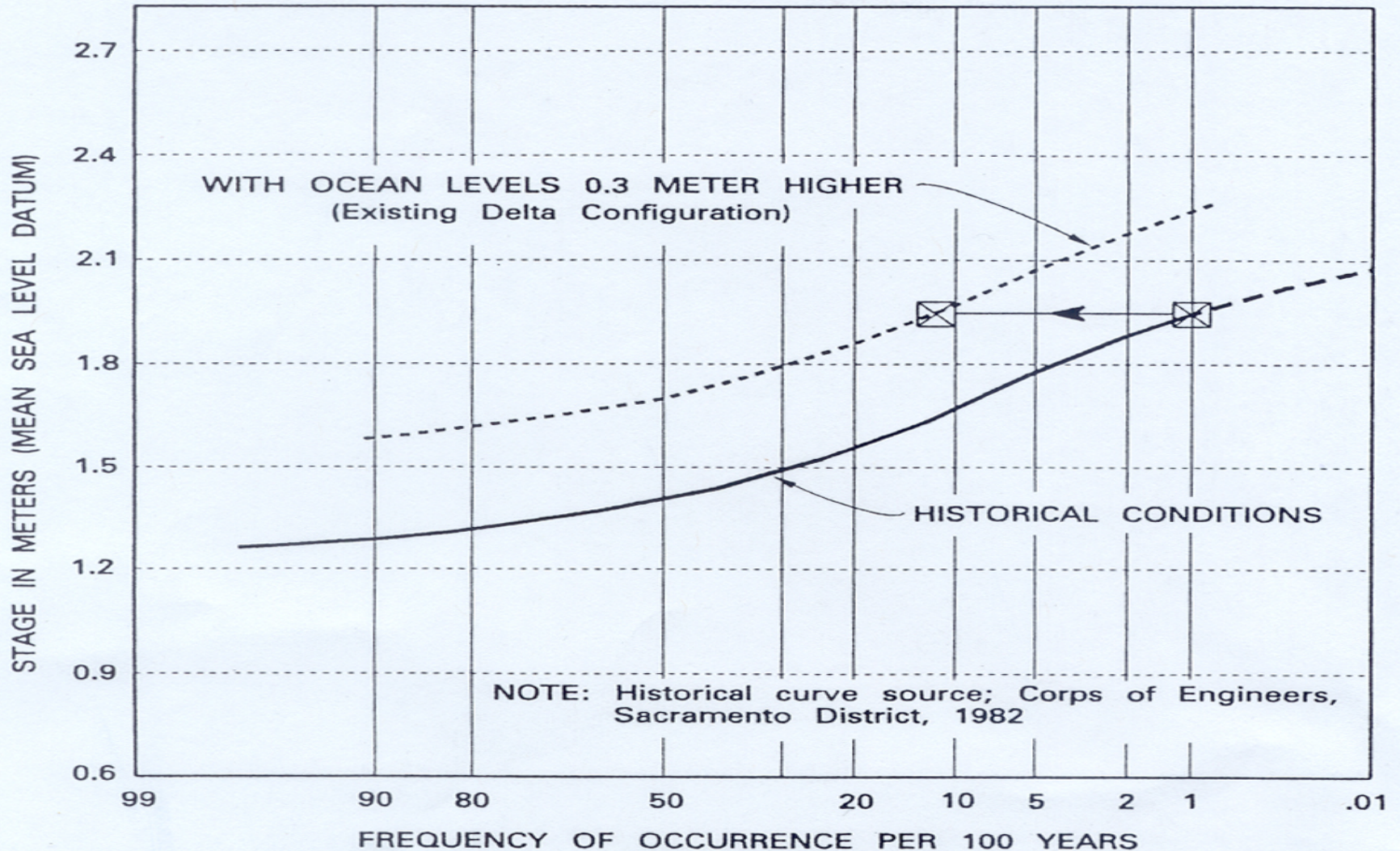
# More Coastal Erosion

## EROSION

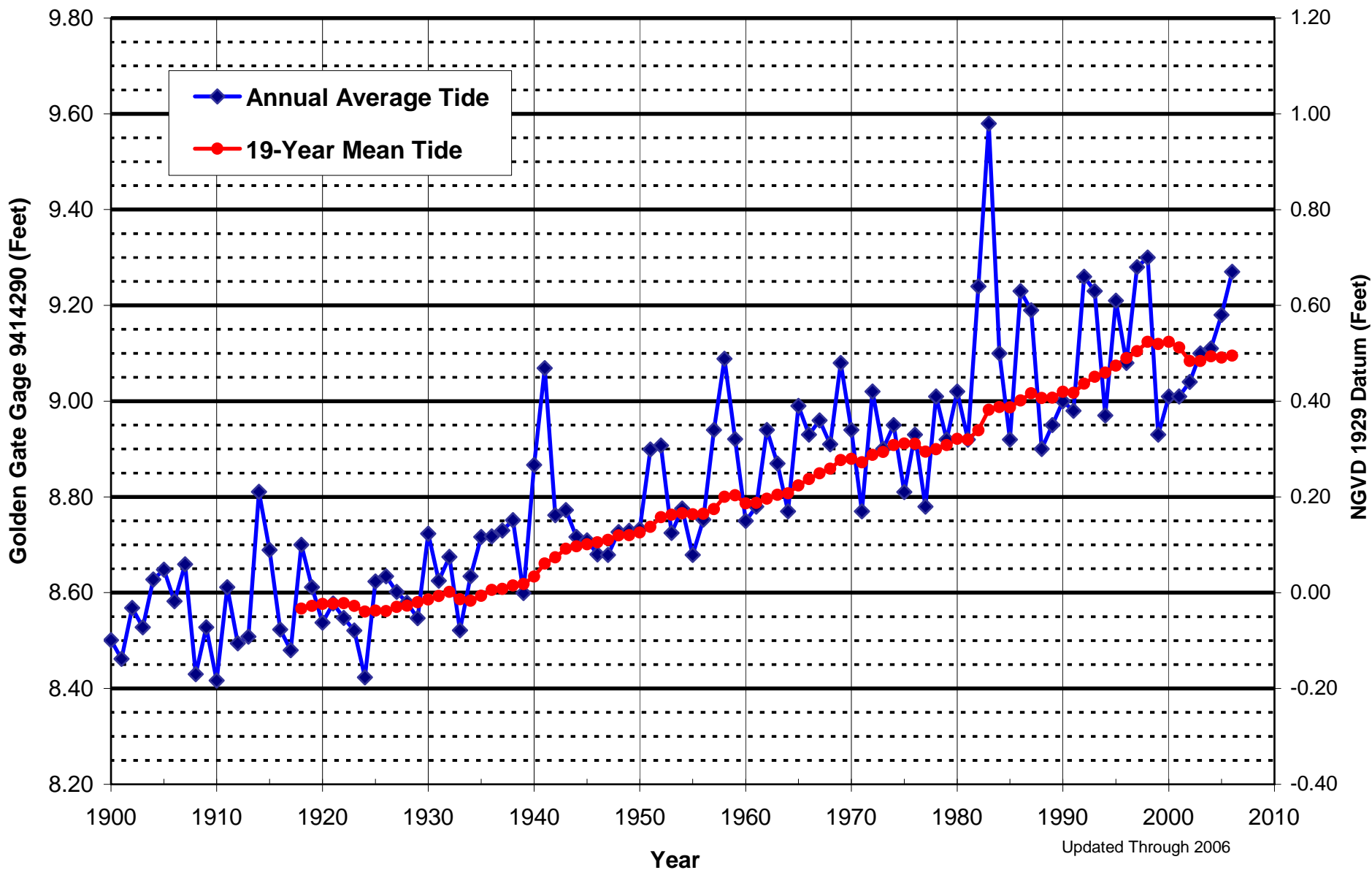




# Antioch chart



# Golden Gate Annual Average and 19-Year Mean Tide Levels



# Possible Effect on CVP-SWP Water Exports

- From preliminary DWR study for 2050 with four scenarios:
  - Average supply change: --10 to + 2 percent
  - 6 year dry period change: --17 to + 5
  - BUT remember the base has a dry period shortage of around 40 percent already

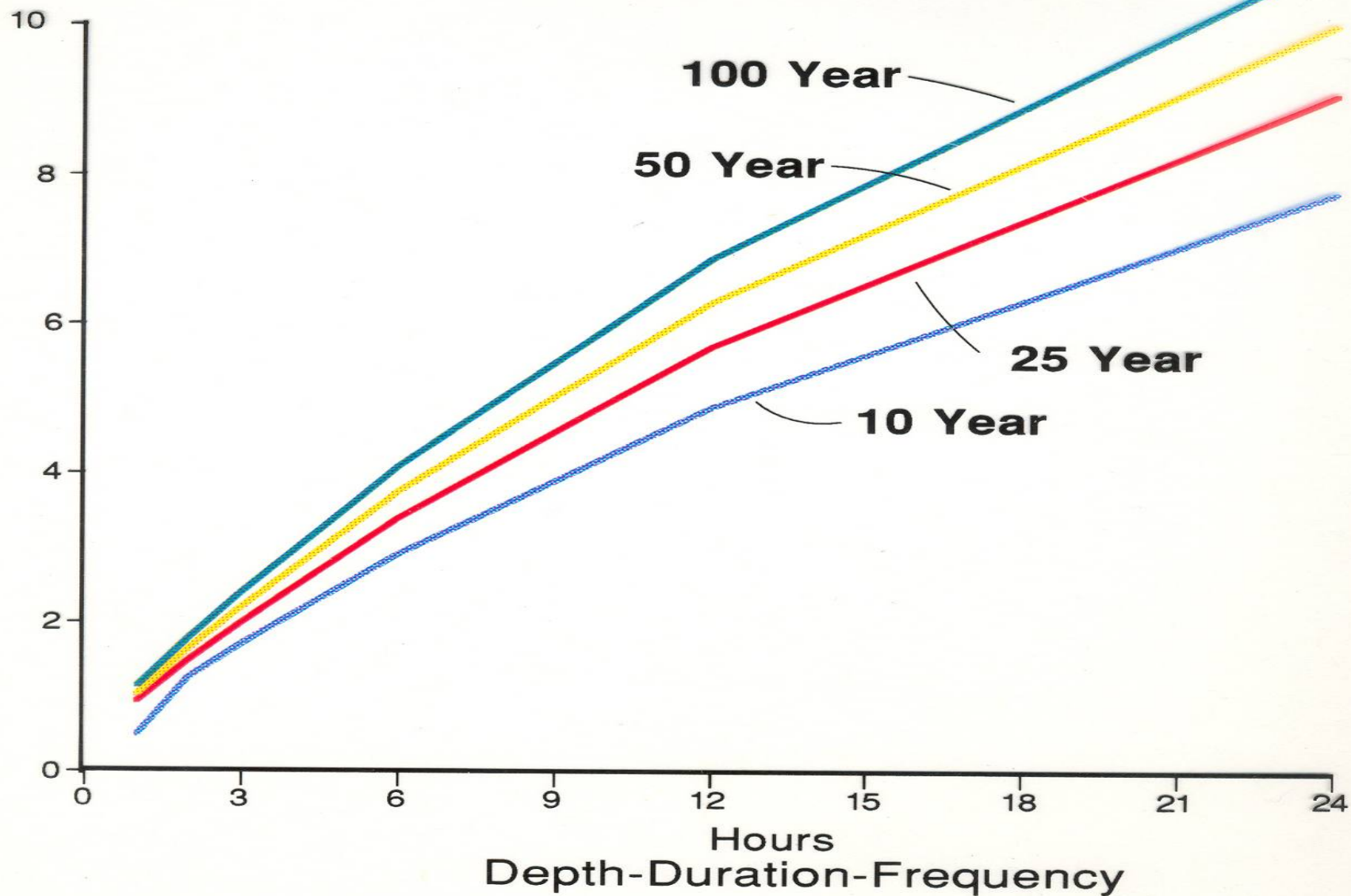
# Possible Flood Increase

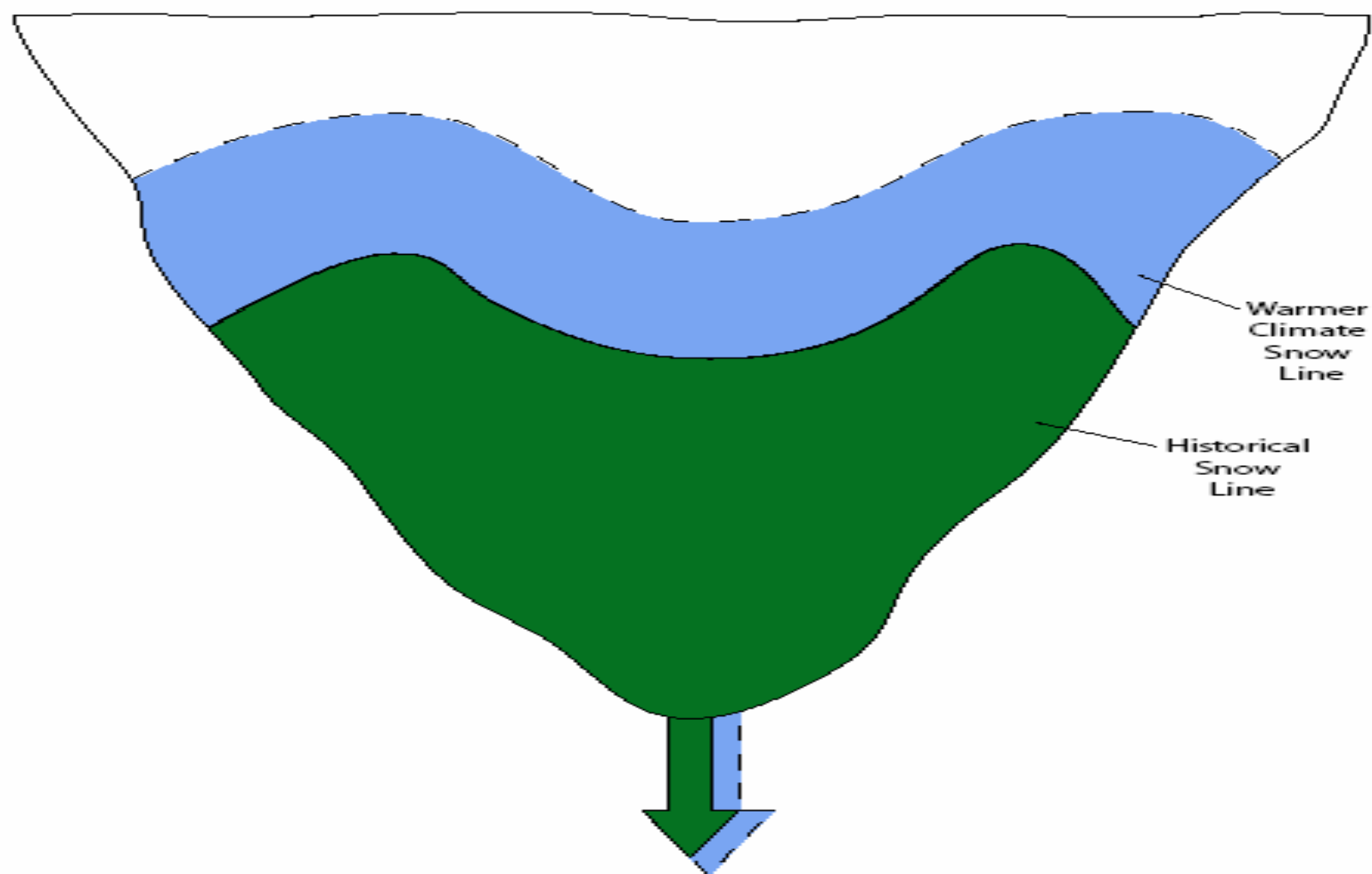
- For mountain basins, higher snow levels during storms means more rain runoff contributing area.
- Storm rainfall intensity tends to increase with warmer temperatures, other parameters being the same.
- Some indication for storm drainage design of increasing intensity of rainstorms.



# Blue Canyon

Precipitation in Inches

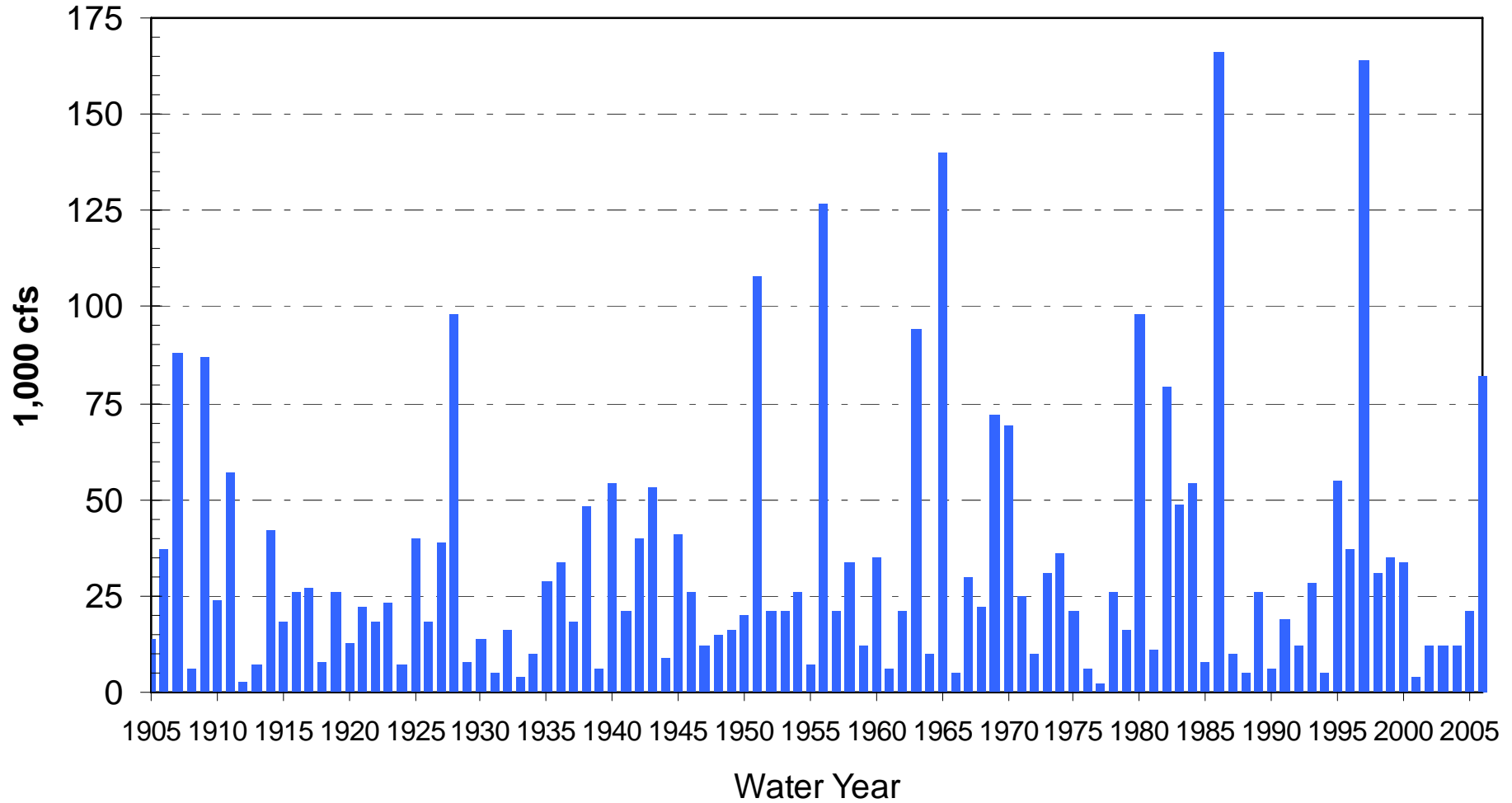




Effect of Warmer Climate on Winter Flood Producing Area

# American River Runoff Annual Maximum 3-Day Flow

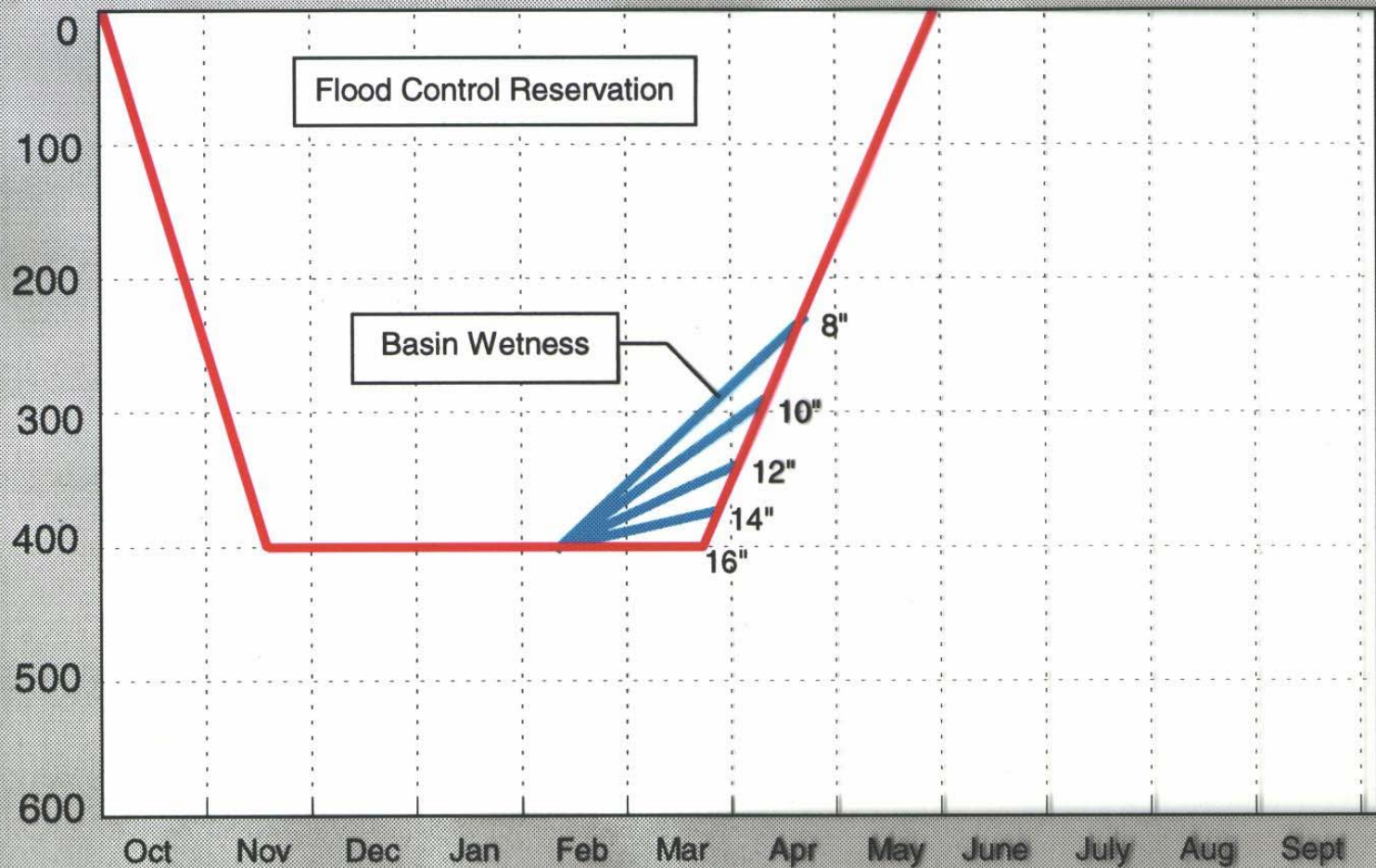
Unimpaired Runoff at Fair Oaks



Data from Corps of Engineers Sacramento District

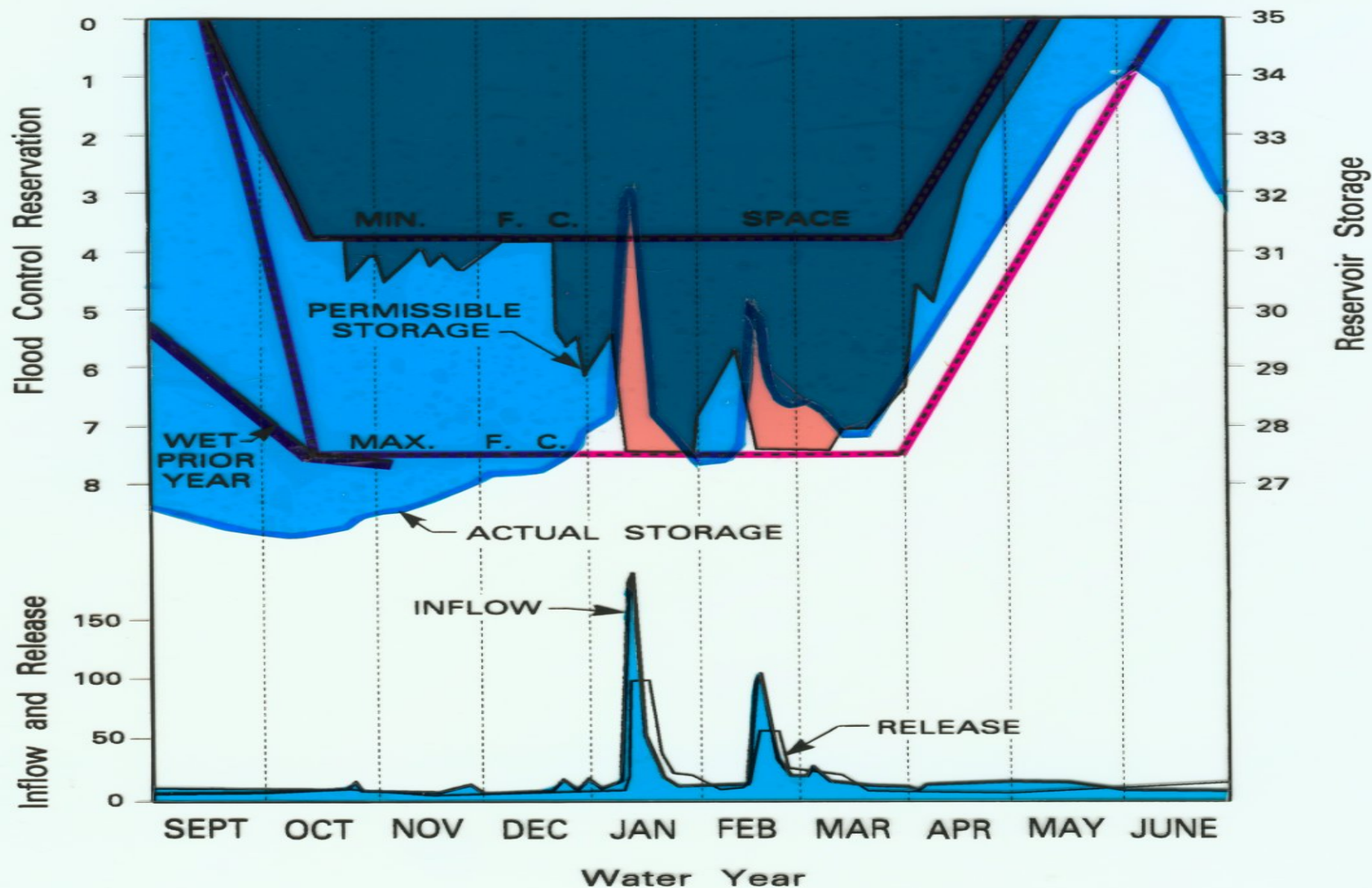
# Folsom Flood Control Diagram

Thousand Acre-Feet





# TYPICAL EXAMPLE RESERVOIR FLOOD CONTROL OPERATION



# Slightly Higher Water Use

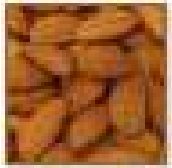
- Farm and landscape water consumption goes up with temperature, around 10 percent for 3° C, other factors constant.
- Higher dewpoints reduce water use
- Higher carbon dioxide reduces use some for most plants.
- With warming, planting dates for annual crops will probably change.

# CA agric, from Peterson



\$31 billion as income (2004)

Highest agricultural crop value in the USA for over 50 consecutive years



Half of the fruits, nuts and vegetables in the USA

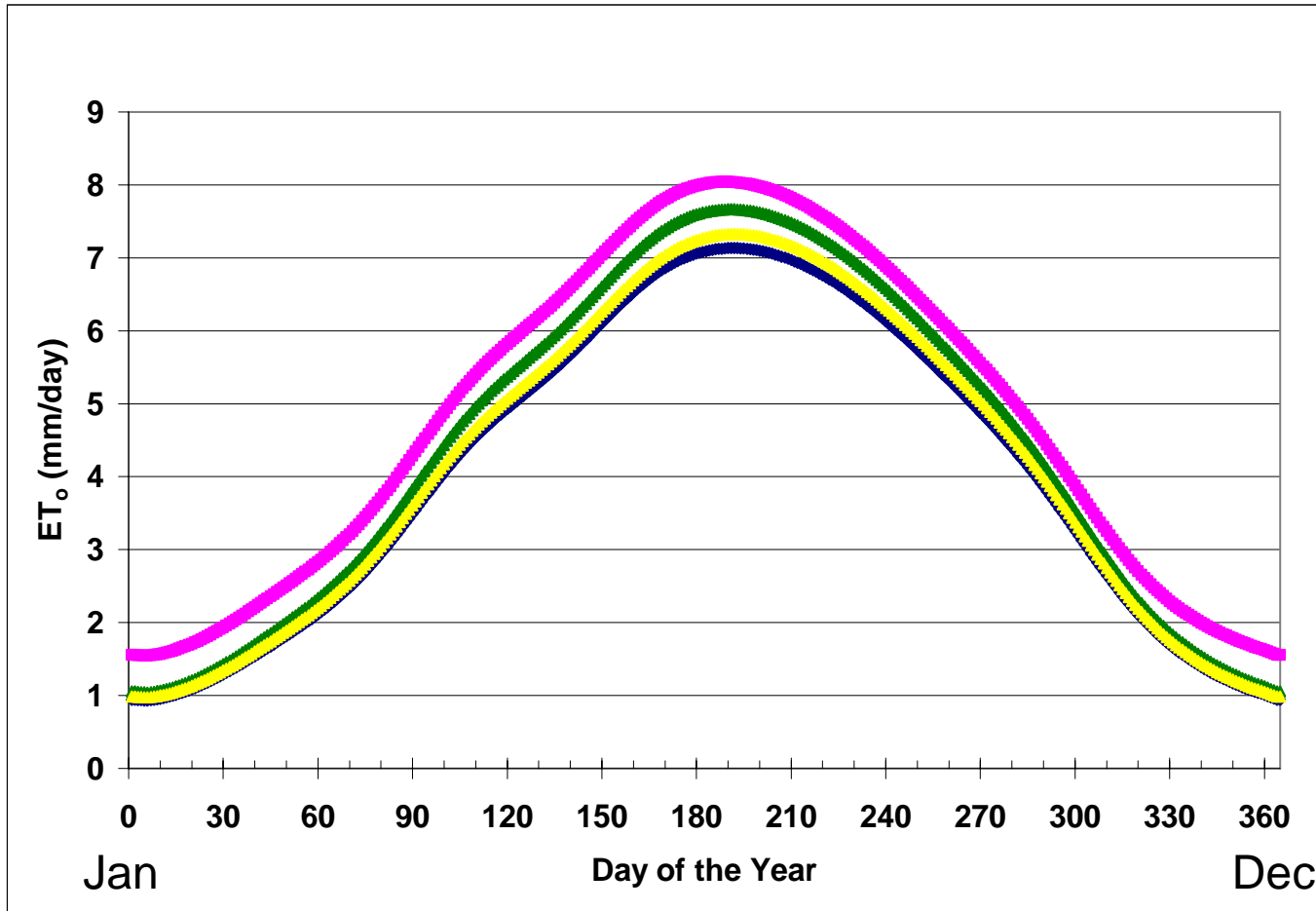
28 million acres in some type of agricultural production (1997)



Mild, Sunny climate; deep rich soils; Infrastructure (water, transport, labor)

NASS 2006; CADFA 2006

# ET simulations slide



■ +Air Temp    ■ +Air & Dew Pt Temp    ■ +Temp & Canopy Res    ■ Current



# Warmer River Water Temperatures

- There are likely to be more problems for cold water fish like salmon, steelhead and trout from warmer temperatures.
- Warmer air temperatures mean warmer water temperatures.
- Reduced and earlier snowmelt means less cold water pools behind major foothill reservoirs.
- Delta smelt near top of their range now, which is 24 - 25° C, or 75 to 77° F.

# Calif. Greenhouse Gas Goals

- By 2010- Reduce to 2000 emission levels  
--by 59 million tons or 11 % below  
“business as usual”
- By 2020- Reduce to 1990 levels—by 145  
million tons or 25 % below “BAS”
- By 2050- Reduce to 80 percent below  
1990 levels.
- Director Snow want DWR to do its part,  
primarily focusing on adaptation.

# Ararat Cloud Cap

